US012219357B2

(12) **United States Patent**
Henry et al.

(10) **Patent No.: US 12,219,357 B2**
(45) **Date of Patent: Feb. 4, 2025**

(54) **MANAGEMENT OF AN ADAPTIVE RELAY METHOD FOR LOST-DEVICE BLUETOOTH LOW ENERGY SIGNALING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **18/590,763**

(22) Filed: **Feb. 28, 2024**

(65) **Prior Publication Data**

US 2024/0205678 A1 Jun. 20, 2024

Related U.S. Application Data

(63) Continuation of application No. 18/045,273, filed on Oct. 10, 2022, now Pat. No. 11,956,637, which is a

(Continued)

(51) **Int. Cl.**

H04W 4/02	(2018.01)
H04W 4/029	(2018.01)
H04W 12/12	(2021.01)
H04W 12/79	(2021.01)
H04W 24/10	(2009.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H04W 12/12*** (2013.01); ***H04W 4/023*** (2013.01); ***H04W 4/029*** (2018.02); ***H04W 12/79*** (2021.01); ***H04W 24/10*** (2013.01); ***H04W 48/16*** (2013.01); ***H04W 48/20*** (2013.01); ***H04W 76/16*** (2018.02); *H04W 88/04* (2013.01); *H04W 88/08* (2013.01); *H04W 88/12* (2013.01); *H04W 92/10* (2013.01); *H04W 92/12* (2013.01)

(58) **Field of Classification Search**

CPC H04B 17/0082–409; H04L 63/02–308; H04L 2209/80–805; H04W 4/02–029; H04W 4/70–80; H04W 12/009–80; H04W 24/02–10; H04W 48/02–20; H04W 64/003–006; H04W 76/10–50; H04W 84/005–22; H04W 88/005–188; H04W 92/02–24

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

11,503,470 B2 * 11/2022 Henry H04W 12/12
11,956,637 B2 * 4/2024 Henry H04W 12/12

* cited by examiner

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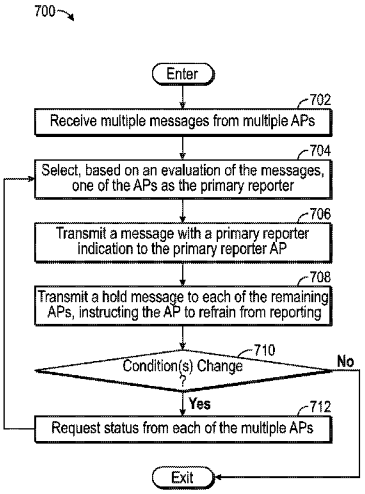
(74) *Attorney, Agent, or Firm* — Patterson + Sheridan, LLP

(57) **ABSTRACT**

Techniques and apparatus for managing a message relaying system are described. One technique includes an access point (AP) detecting a first signal and a second signal from a computing device. A validation of the first signal is performed based on parameters of the first signal and the second signal. After the validation, information associated with the first signal is transmitted to a computing system. In another technique, the computing system may designate one of multiple APs reporting information regarding first signals as a primary reporting AP and designate the remaining APs as secondary reporting APs. The computing system may instruct the secondary reporting APs to refrain from reporting information regarding first signals to the computing system.

20 Claims, 13 Drawing Sheets


700
Enter
702
Receive multiple messages from multiple APs
704
Select, based on an evaluation of the messages, one of the APs as the primary reporter
706
Transmit a message with a primary reporter indication to the primary reporter AP
708
Transmit a hold message to each of the remaining APs, instructing the AP to refrain from reporting
710
Condition(s) Change ?
No
Yes
712
Request status from each of the multiple APs
Exit

Related U.S. Application Data

continuation of application No. 16/989,758, filed on Aug. 10, 2020, now Pat. No. 11,503,470.

(51) **Int. Cl.**

H04W 48/16	(2009.01)
H04W 48/20	(2009.01)
H04W 76/16	(2018.01)
H04W 88/04	(2009.01)
H04W 88/08	(2009.01)
H04W 88/12	(2009.01)
H04W 92/10	(2009.01)
H04W 92/12	(2009.01)

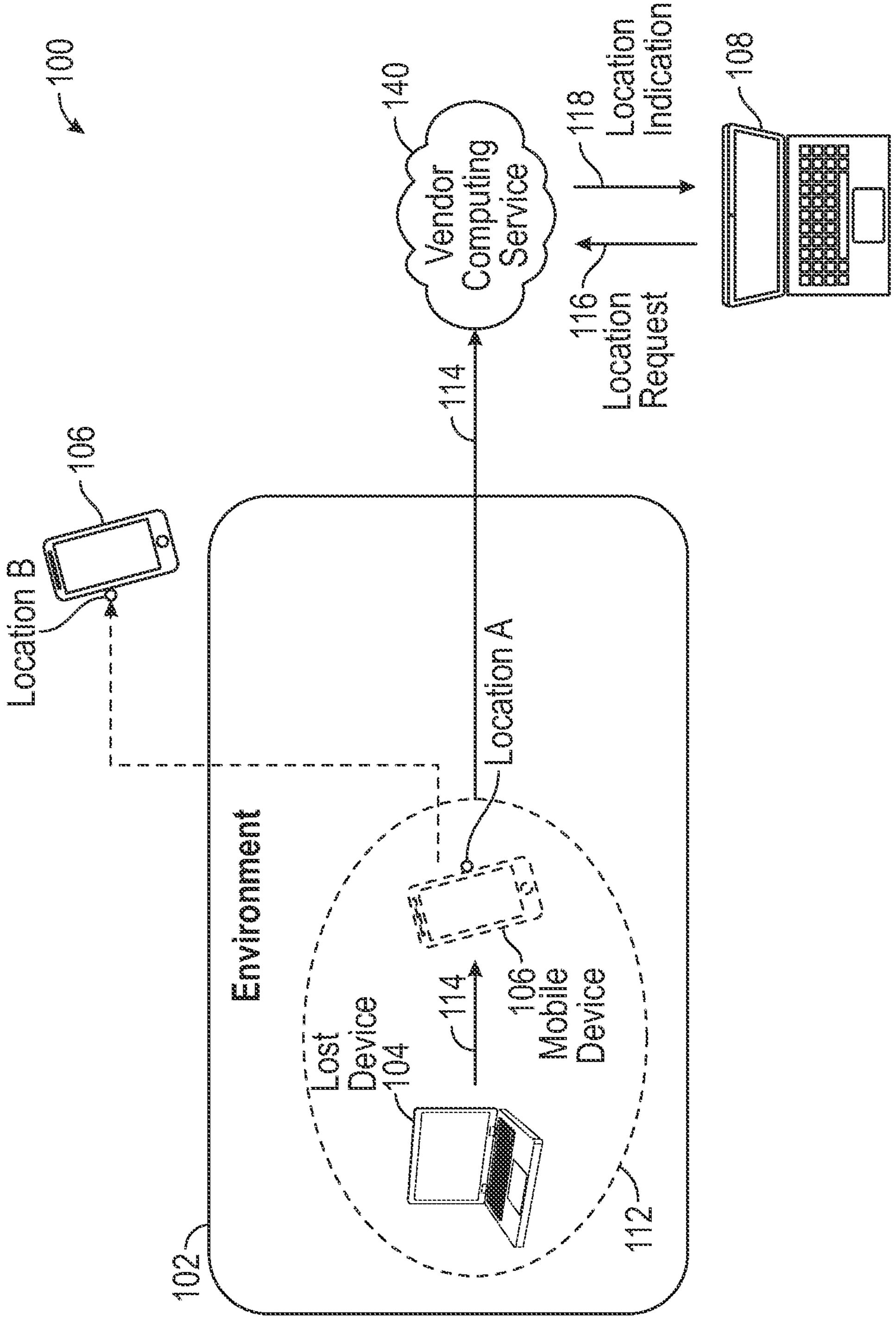

100
106
Location B
Environment
Location A
Lost Device 104
114
106 Mobile Device
102
112
114
140
Vendor Computing Service
116 Location Request
118 Location Indication
108

FIG. 1

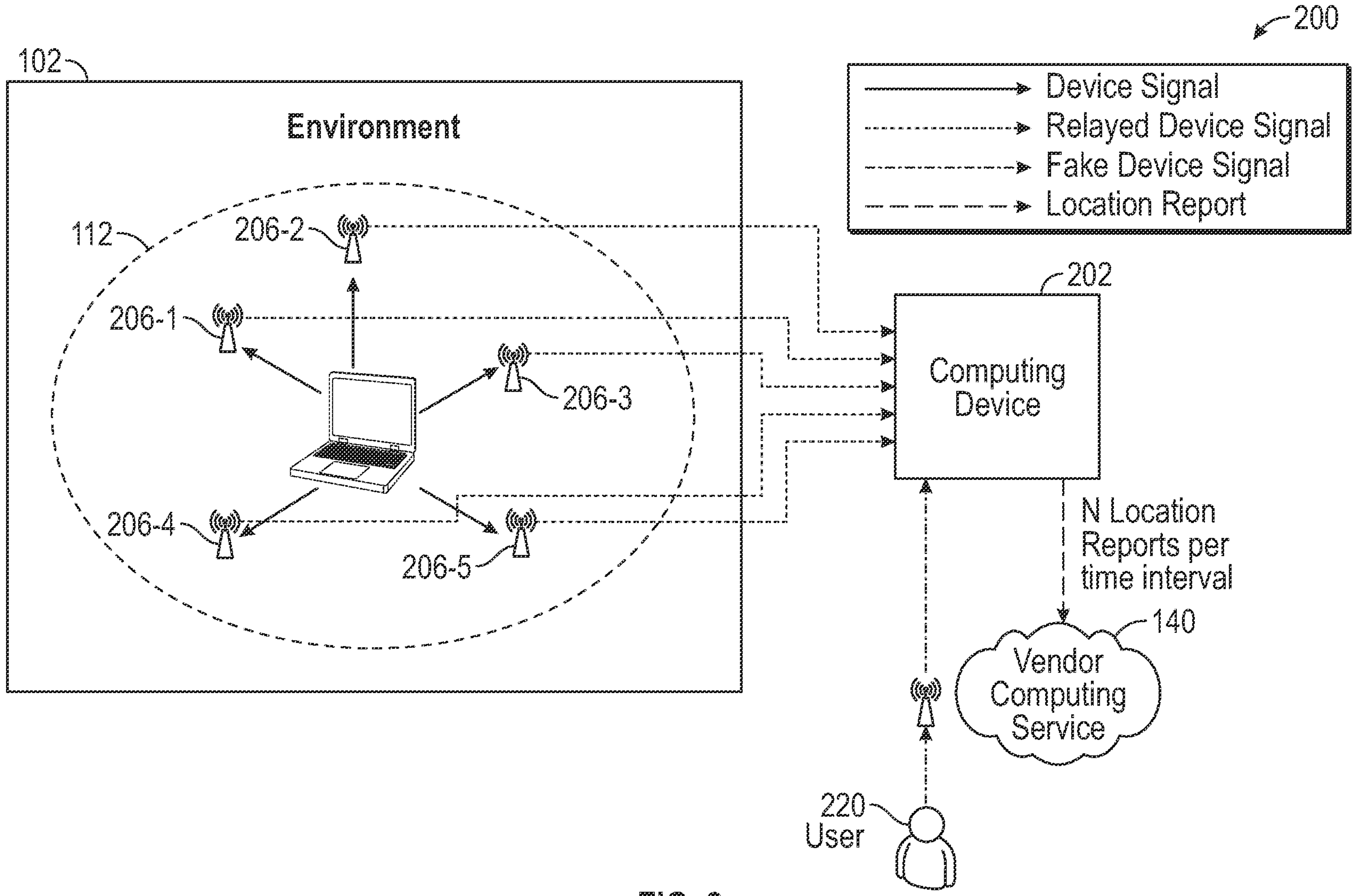

200
Device Signal
Relayed Device Signal
Fake Device Signal
Location Report
102
Environment
112
206-2
206-1
206-3
206-4
206-5
202
Computing Device
N Location Reports per time interval
140
Vendor Computing Service
220
User

FIG. 2

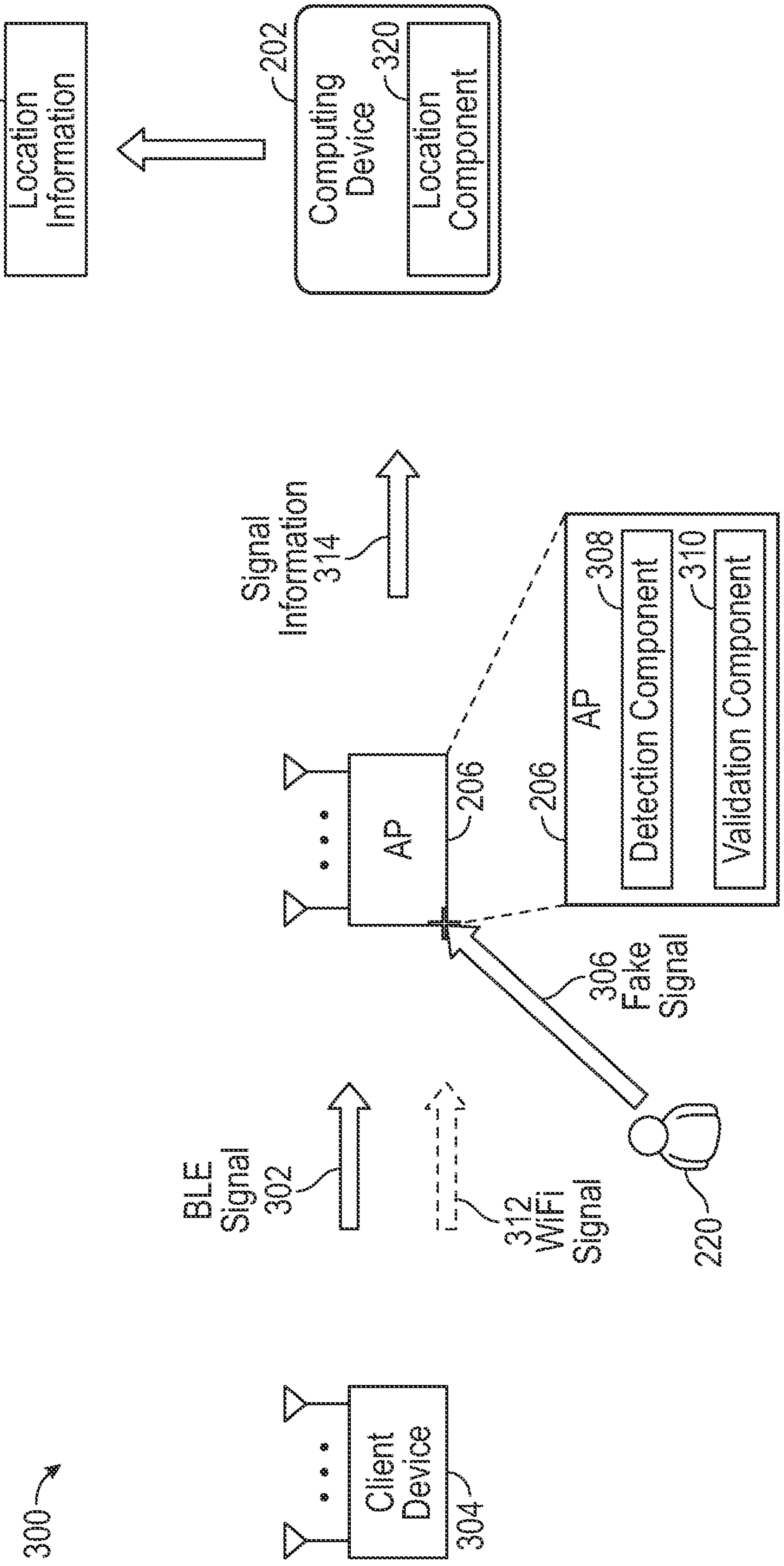

300
Client Device
304
BLE Signal
302
312
WiFi Signal
220
306
Fake Signal
AP
206
AP
206
Detection Component
308
Validation Component
310
Signal Information
314
Computing Device
202
Location Component
320
Location Information
322

FIG. 3

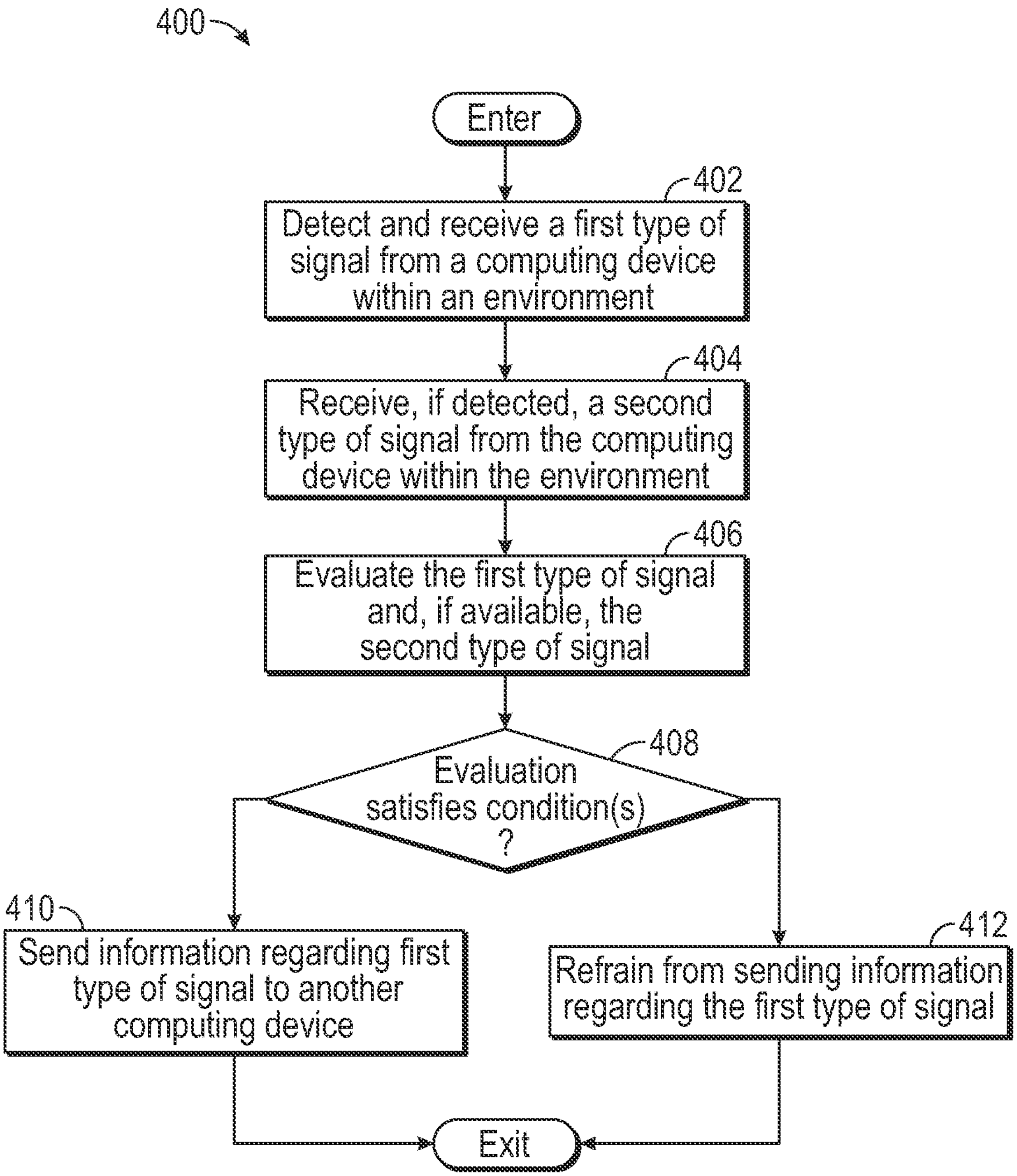

400
Enter
402
Detect and receive a first type of signal from a computing device within an environment
404
Receive, if detected, a second type of signal from the computing device within the environment
406
Evaluate the first type of signal and, if available, the second type of signal
408
Evaluation satisfies condition(s) ?
410
Send information regarding first type of signal to another computing device
412
Refrain from sending information regarding the first type of signal
Exit

FIG. 4

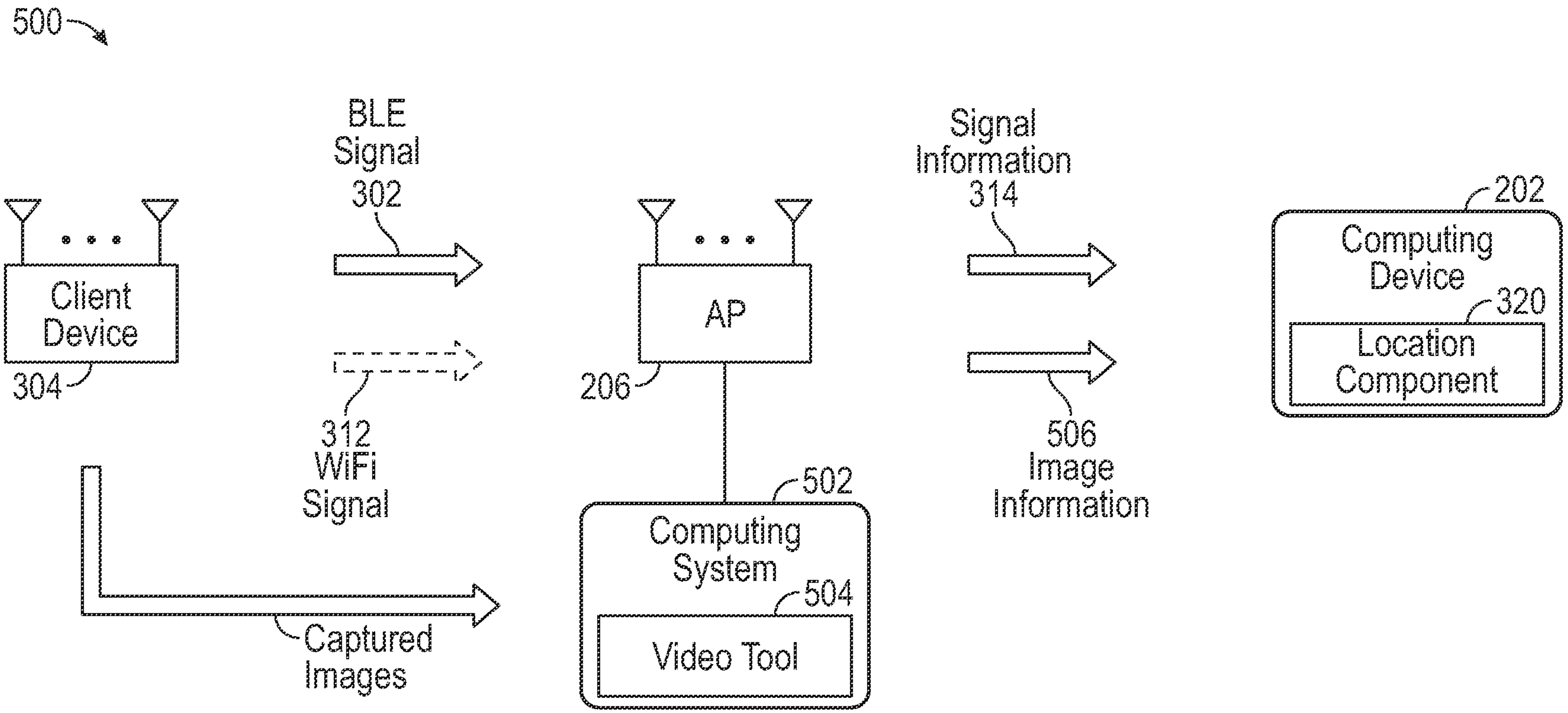

500
Client Device
304
BLE Signal 302
312 WiFi Signal
Captured Images
AP
206
Computing System
502
504
Video Tool
Signal Information 314
506 Image Information
202
Computing Device
320
Location Component

FIG. 5

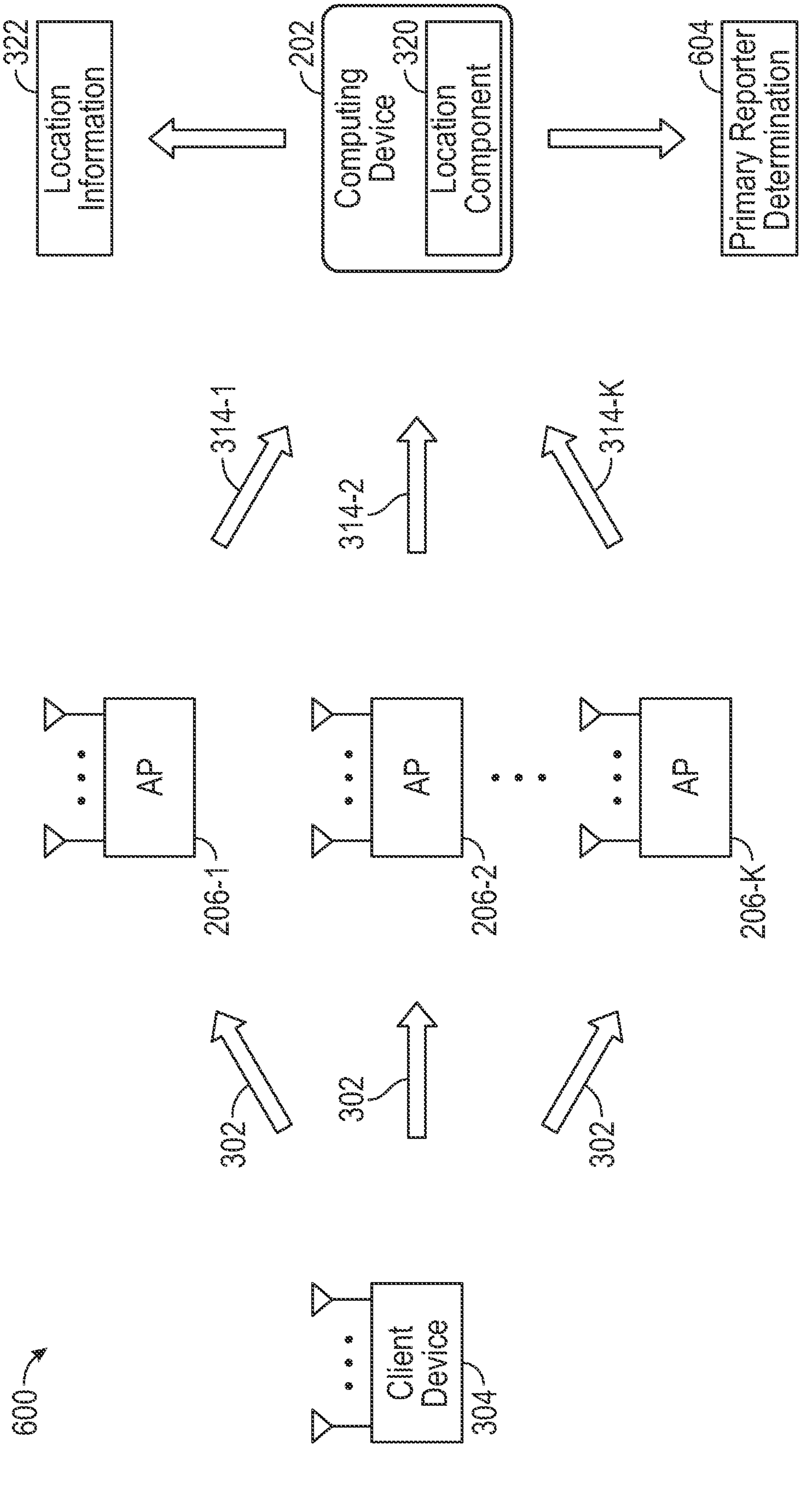

600
Client Device
304
302
302
302
AP
206-1
AP
206-2
AP
206-K
314-1
314-2
314-K
Location Information
322
Computing Device
202
Location Component
320
Primary Reporter Determination
604

FIG. 6A

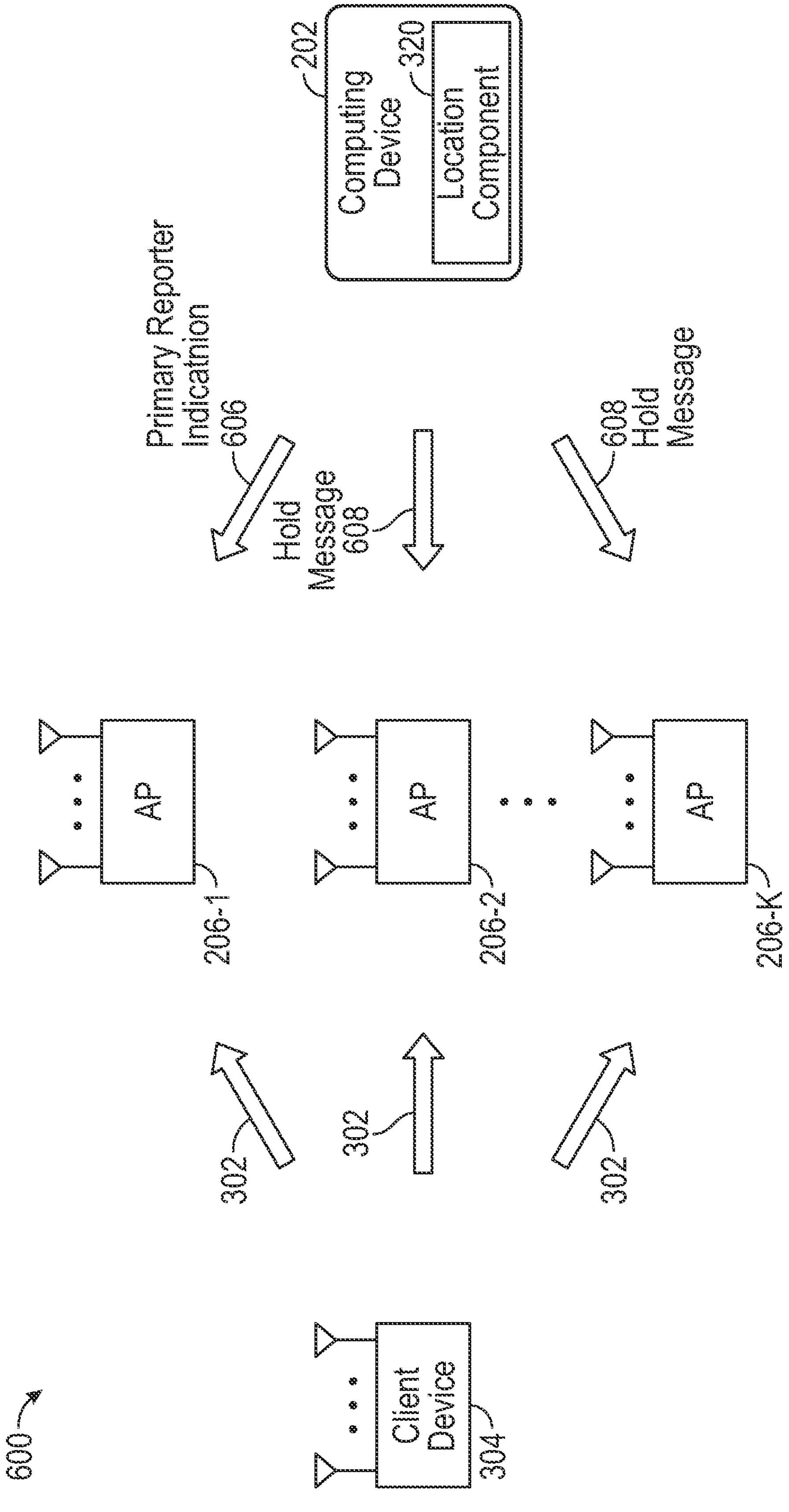

600
Client Device
304
302
302
302
AP
206-1
AP
206-2
AP
206-K
Primary Reporter Indicatnion
606
Hold Message
608
608
Hold Message
Computing Device
202
Location Component
320

FIG. 6B

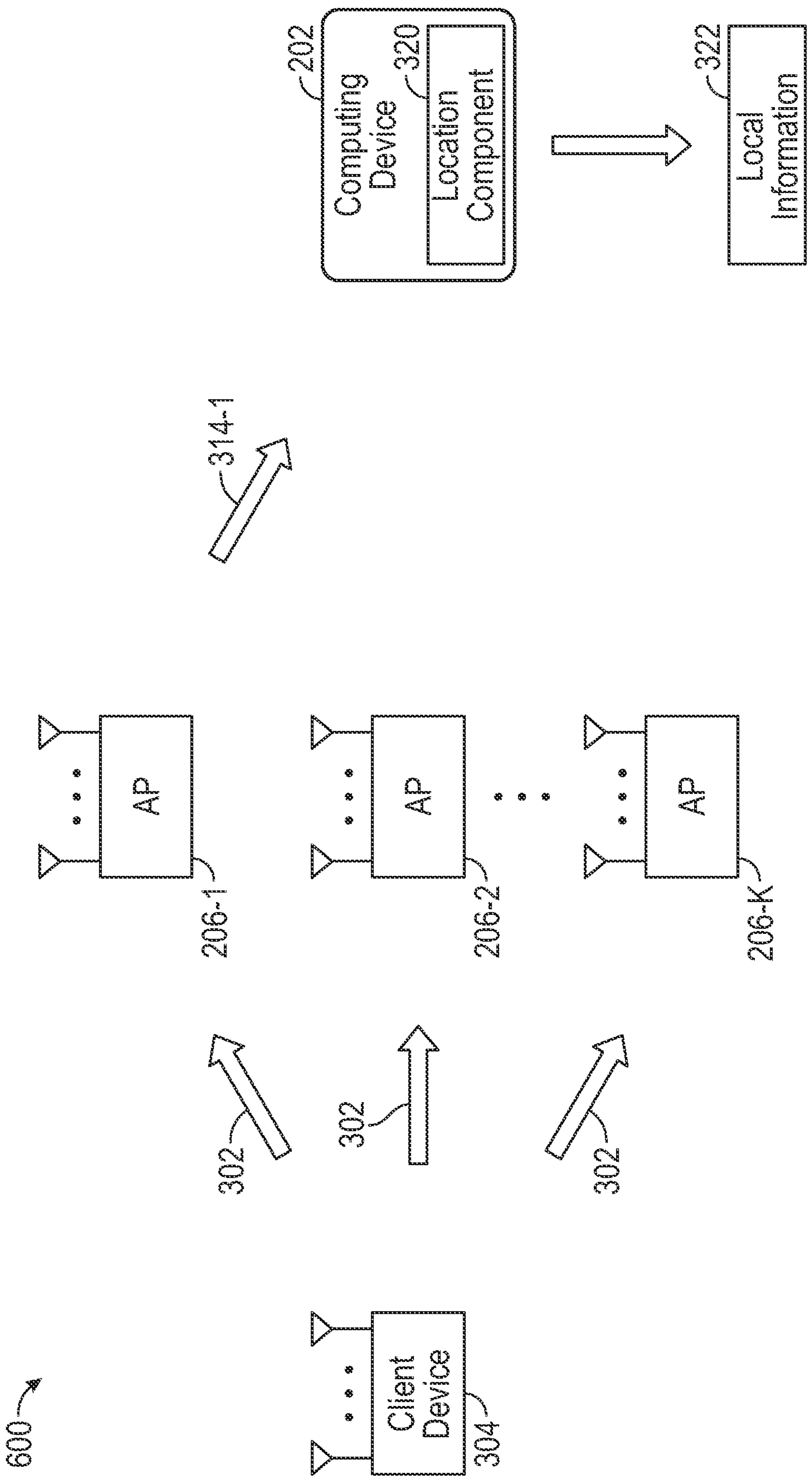

600
Client Device
304
302
302
302
AP
AP
AP
206-1
206-2
206-K
314-1
Computing Device
202
Location Component
320
Local Information
322

FIG. 6C

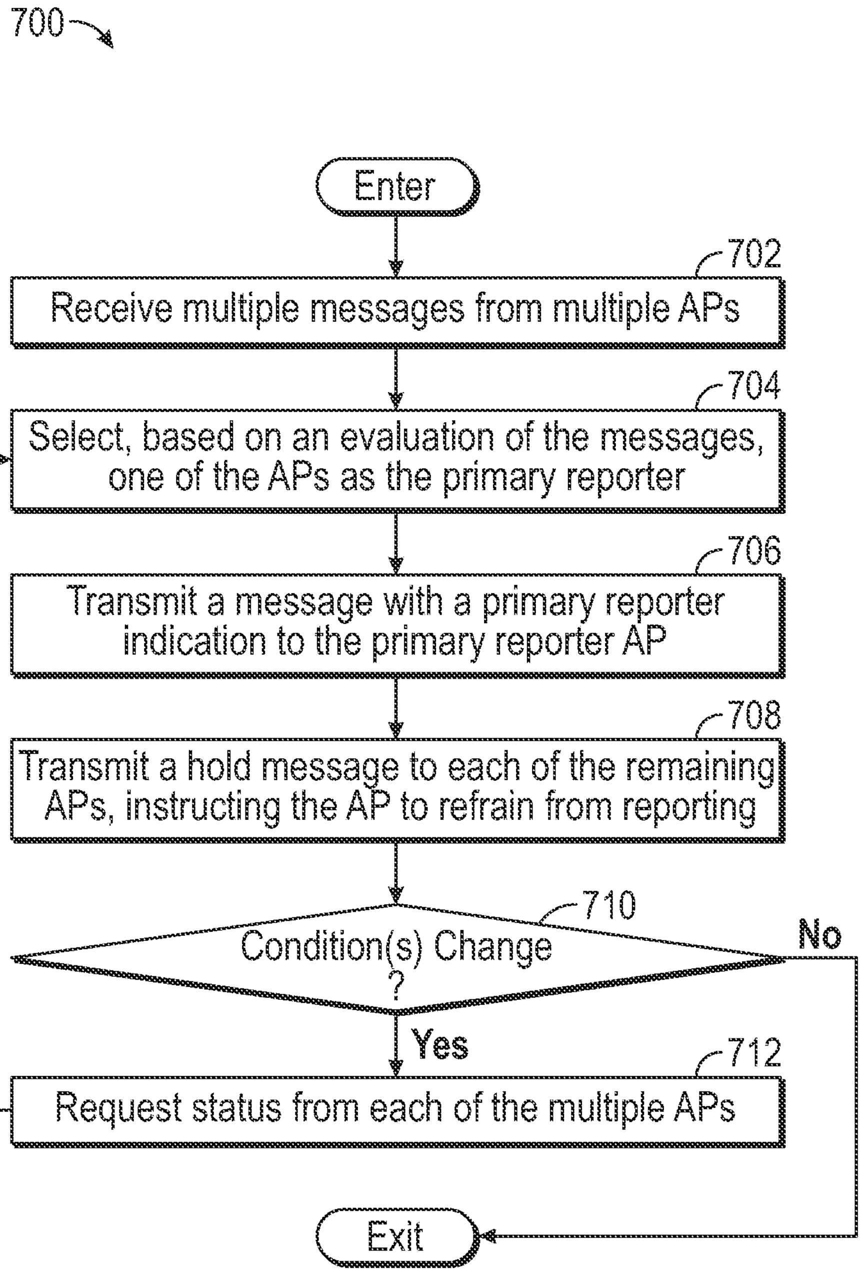

700
Enter
702
Receive multiple messages from multiple APs
704
Select, based on an evaluation of the messages, one of the APs as the primary reporter
706
Transmit a message with a primary reporter indication to the primary reporter AP
708
Transmit a hold message to each of the remaining APs, instructing the AP to refrain from reporting
710
Condition(s) Change ?
No
Yes
712
Request status from each of the multiple APs
Exit

FIG. 7

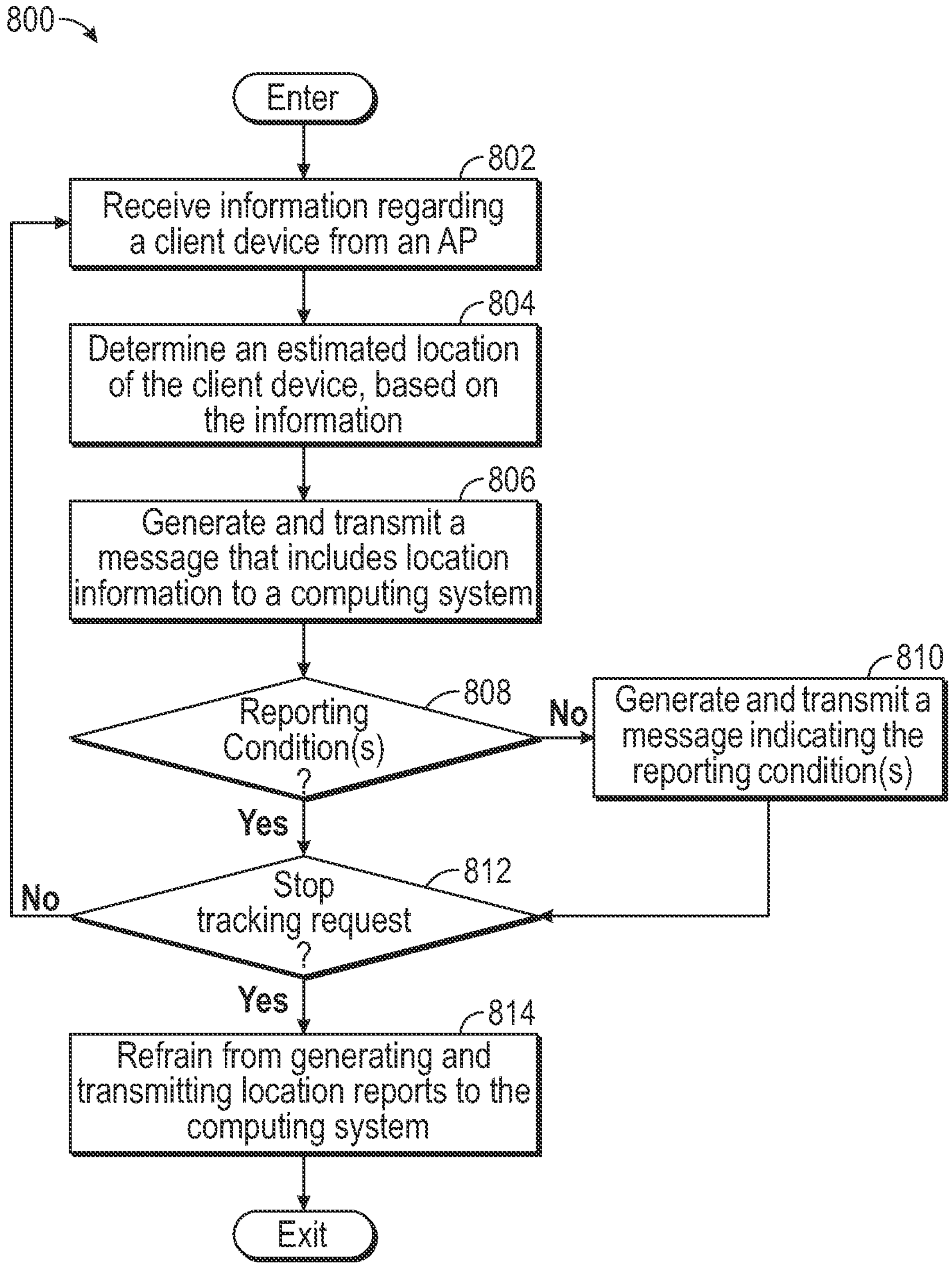

800
Enter
802
Receive information regarding a client device from an AP
804
Determine an estimated location of the client device, based on the information
806
Generate and transmit a message that includes location information to a computing system
808
Reporting Condition(s) ?
No
810
Generate and transmit a message indicating the reporting condition(s)
Yes
812
Stop tracking request ?
No
Yes
814
Refrain from generating and transmitting location reports to the computing system
Exit

FIG. 8

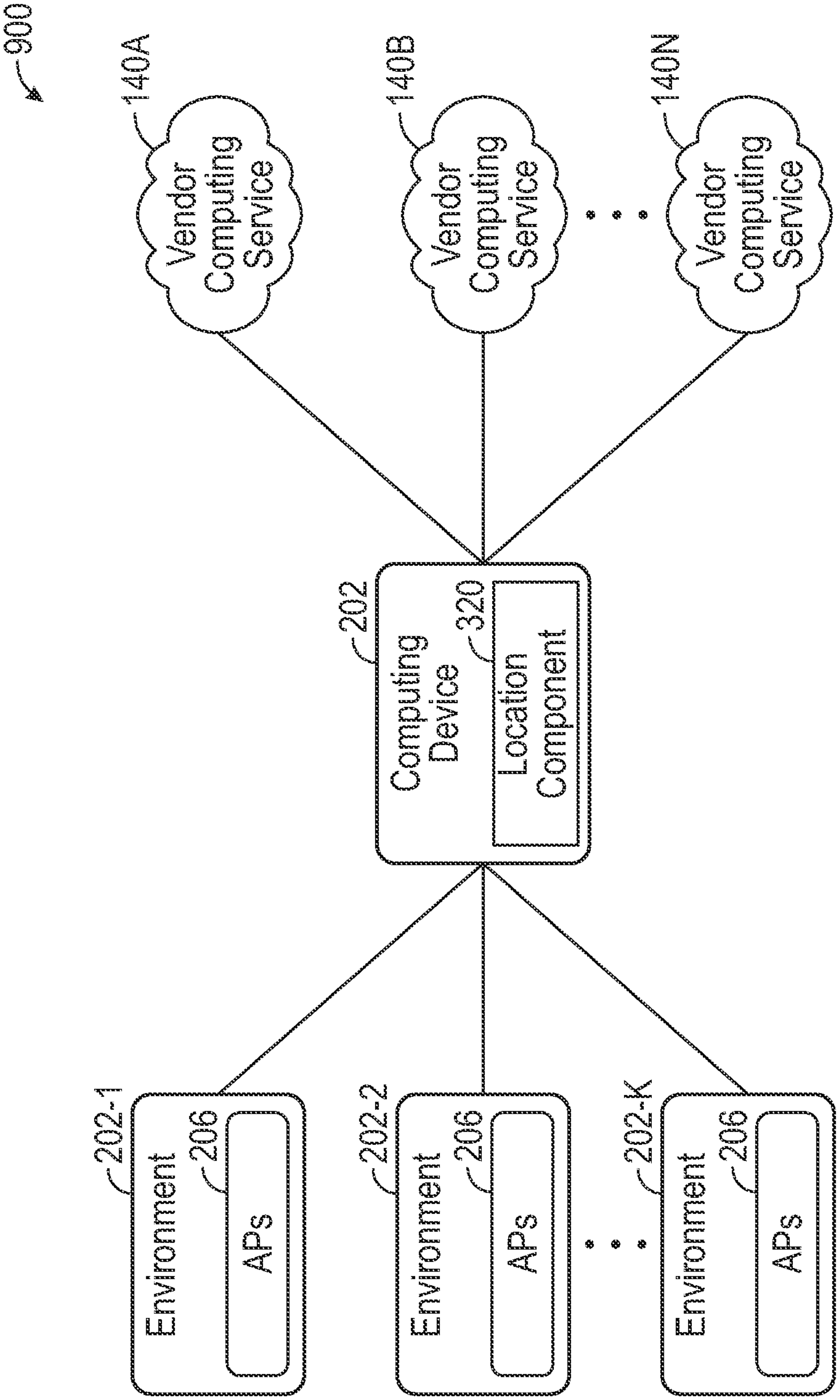

900
140A
Vendor Computing Service
140B
Vendor Computing Service
140N
Vendor Computing Service
202
Computing Device
320
Location Component
202-1
Environment
206
APs
202-2
Environment
206
APs
202-K
Environment
206
APs

FIG. 9

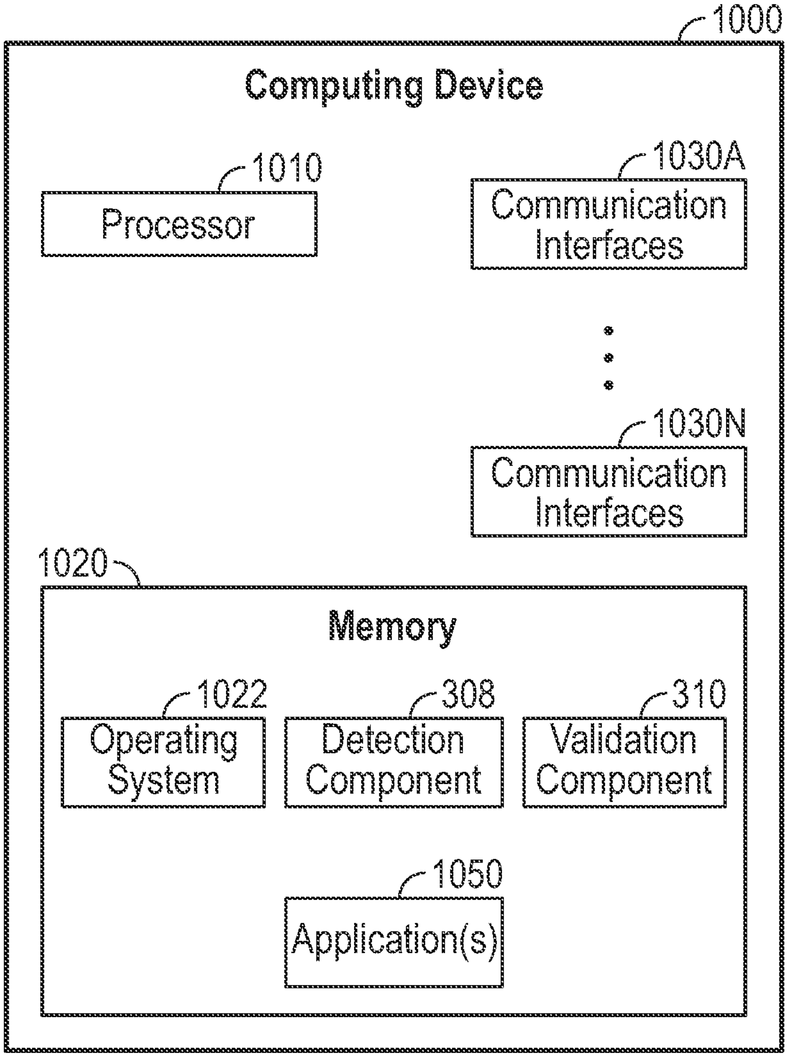

1000
Computing Device
1010
Processor
1030A
Communication Interfaces
1030N
Communication Interfaces
1020
Memory
1022
Operating System
308
Detection Component
310
Validation Component
1050
Application(s)

FIG. 10

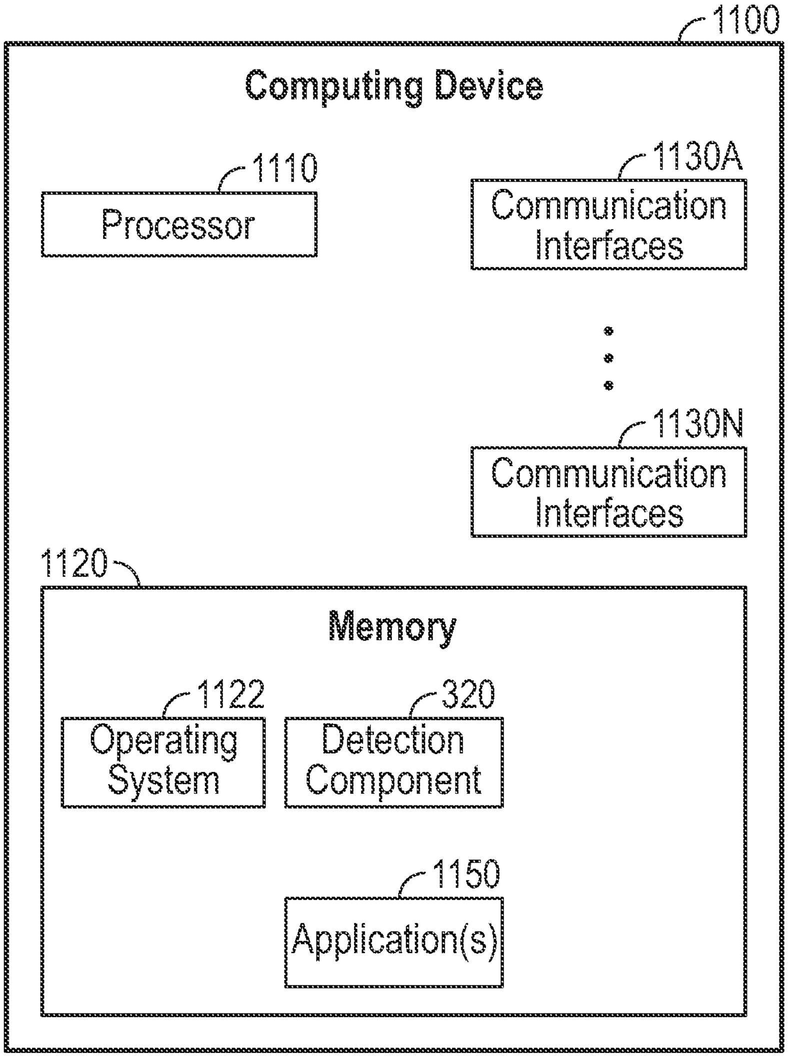

1100
Computing Device
1110
Processor
1130A
Communication Interfaces
1130N
Communication Interfaces
1120
Memory
1122
Operating System
320
Detection Component
1150
Application(s)

FIG. 11

MANAGEMENT OF AN ADAPTIVE RELAY METHOD FOR LOST-DEVICE BLUETOOTH LOW ENERGY SIGNALING

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of co-pending U.S. patent application Ser. No. 18/045,273 filed Oct. 10, 2022, which is a continuation of U.S. patent application Ser. No. 16/989,758 filed Aug. 10, 2020, which issued on Nov. 15, 2022 as U.S. Pat. No. 11,503,470. The aforementioned related patent applications are herein incorporated by reference in their entireties and for all applicable purposes.

TECHNICAL FIELD

Embodiments presented in this disclosure generally relate to techniques for managing a message relaying system used for determining a location of a computing device.

BACKGROUND

Some device vendors (e.g., device manufacturers) implement a messaging system between the computing devices in their ecosystem that can be used to locate lost computing devices. For example, in this messaging system, an idle or offline device can broadcast encrypted messages. Other devices within the vicinity of the idle or offline device can detect the broadcast messages and relay the messages to a cloud computing system associated with the device vendor. The cloud computing system can determine an approximate location of the idle or offline device, based on the relayed messages from the other devices. A user (e.g., owner) of the idle or offline device can access the cloud computing system to determine the location of the idle or offline device.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate typical embodiments and are therefore not to be considered limiting; other equally effective embodiments are contemplated.

FIG. **1** illustrates an example scenario in which a neighboring device is in presence of a missing computing device.

FIG. **2** illustrates an example system for determining the location of a computing device, according to one embodiment.

FIG. **3** illustrates an example workflow for validating device signals detected from a computing device, according to one embodiment.

FIG. **4** is a flowchart of a method for validating device signals detected from a computing device, according to one embodiment.

FIG. **5** illustrates an example workflow for performing object detection, according to one embodiment.

FIGS. **6**A-**6**C illustrate a workflow for managing a message relaying system, according to one embodiment.

FIG. **7** is a flowchart of a method for managing a message relaying system, according to one embodiment.

FIG. **8** is a flowchart of another method for managing a message relaying system, according to one embodiment.

FIG. **9** illustrates an example system for interacting with multiple vendor computing services, according to one embodiment.

FIG. **10** illustrates an example computing device, according to one embodiment.

FIG. **11** illustrates an example computing device, according to one embodiment.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially used in other embodiments without specific recitation.

DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

One embodiment presented in this disclosure is a computer-implemented method performed by an access point (AP). The computer-implemented method includes detecting a first signal and a second signal from a computing device within an environment. The computer-implemented method also includes performing a validation of the first signal, based at least in part on one or more parameters of the first signal and one or more parameters of the second signal. The computer-implemented method further includes after performing the validation of the first signal, transmitting information regarding the first signal to a computing system.

Another embodiment presented in this disclosure is an AP. The AP generally includes a processor and a memory containing a program that, when executed by the processor, performs an operation. The operation generally includes detecting a first signal and a second signal from a computing device within an environment. The operation also includes performing a validation of the first signal, based at least in part on one or more parameters of the first signal and one or more parameters of the second signal. The operation further includes after performing the validation of the first signal, transmitting information regarding the first signal to a computing system.

Another embodiment presented in this disclosure is a computer-implemented method performed by an apparatus. The computer-implemented method generally includes receiving a plurality of first messages from a plurality of APs. Each first message includes information regarding a device signal received by the AP from a computing device. The computer-implemented method also includes selecting, based on an evaluation of each of the plurality of first messages, one of the plurality of APs as a primary reporting AP. The computer-implemented method further includes transmitting to the first AP a second message comprising an indication that the first AP is the primary reporting AP. The computer-implemented further yet includes, after transmitting the second message, forwarding the first message to a computing system.

EXAMPLE EMBODIMENTS

The location mechanism in messaging systems generally relies on the presence of other computing devices that belong to the same ecosystem as the missing or lost device. However, in some situations, there may not be a neighboring computing device (belonging to the same ecosystem as the missing device) in the vicinity of the missing device. Moreover, in some situations, the neighboring computing device may be in the vicinity of the missing device for a short period of time (e.g., the neighboring computing device may be carried by a user that is passing by the missing device).

FIG. **1**, for example, depicts a reference scenario **100** in which a mobile device **106** is temporarily in the vicinity (or proximity) **112** of a lost device **104** (e.g., laptop) within an (indoor) environment **102**. As shown, the lost device **104** sends (e.g., broadcasts) a device signal **114**, which can be detected by one or more neighboring devices within a vicinity **112** of the lost device **104**. In one particular embodiment, the device signal **114** is an encrypted Bluetooth (BT) signal (or message). In another particular embodiment, the device signal **114** is an encrypted Bluetooth Low Energy (BLE) signal (or message). Here, the device signal **114** is detected by the mobile device **106** when the mobile device **106** is in location A. The mobile device **106**, in turn, relays (or forwards) the device signal **114** to the vendor computing service **140**.

The vendor computing service **140** may be a cloud computing service used for computing devices that belong to the same ecosystem (e.g., computing devices from the same manufacturer, company, etc.). The vendor computing service **140** can allow a user to access the service to request the location of a device that may have been lost by the user. Here, for example, a user submits (via the computing device **108**) a location request **116** for the lost device **104** to the vendor computing service **140**. In response, the vendor computing service **140** returns a location indication **118** indicating the location of the mobile device **106** at the time that the mobile device **106** detected (and/or relayed) the device signal **114** (e.g., location A). In some cases, however, the detection and location association may be temporal. For example, because the location indication **118** is based on the position of the mobile device **106** at the time the mobile device **106** detected the device signal **114**, the location indication **118** may not include accurate location information for the lost device **104** at the time the user accesses the vendor computing service **140**. In this case, for example, the mobile device **106** has transitioned from location A to location B (outside of the environment **102**) by the time the user accesses the vendor computing service **140**.

In some embodiments described herein, one or more access points (APs) deployed within an environment **102** can be utilized to detect and relay device signals **114**. FIG. **2** depicts an example system **200** for using AP(s) **206** to determine the location of a missing device **104**, according to one embodiment. As shown, APs **206 1-5** are deployed (e.g., in fixed locations) within the environment **102** and are in vicinity **112** of the lost device **104**. In one embodiment, each AP **206 1-5** is configured to detect certain types of device signals. For example, assuming the device signals are BT/BLE signals, each AP **206 1-5** can incorporate BT/BLE chips that enable the AP to detect BT/BLE signals.

As shown, each AP **206 1-5** detects a device signal **114** (e.g., encrypted BLE signal) broadcast by the lost device **104**, and relays the device signal **114** to the computing device **202**. The computing device **202**, in turn, sends location reports received from the APs **206 1-5** to the vendor computing service **140** (e.g., N location reports per time interval). The vendor computing service **140** can determine the approximate location of the lost device **104**, based on the multiple location reports received from the APs **206 1-5**.

One challenge with using APs **206** to relay device signals is that the relaying system may not be suitable for high density environments with a large number of APs. For example, in medium to high density environments, several APs may detect each device signal broadcast from the lost device **104**, which, in turn, may result in a large number of duplicate messages sent to the vendor computing service **140**. In the example shown in FIG. **2**, the computing device **202** may send N (e.g., five) reports each time interval (e.g., every two seconds) to the vendor computing service **140**.

Additionally, in some cases, the detection and location association may also be temporal with the use of APs **206**. For example, the lost device **104** may stop broadcasting (e.g., due to an empty battery), the lost device **104** may move within the environment **102** (e.g., a user may have picked up the lost device **104**), etc. In these examples, the location information based on the broadcast device signals may be inaccurate and non-informative. For instance, the location information may indicate that the lost device **104** was last seen at location (X, Y), two hours ago, but such information may not be able to indicate if the lost device **104** is currently at location (X, Y).

Further, in some cases, the relaying among the APs **206** may be susceptible to spoofing by one or more malicious actors. For example, as shown in FIG. **2**, a malicious actor (e.g., user **220**) can attempt to jam, replay, or send fake (or spoofed) BLE messages to an AP in order to have the AP relay that message to the vendor computing service **140**.

Accordingly, embodiments described herein provide techniques for managing a messaging system (e.g., system **200**) in order to identify (missing or lost) computing devices, detect impersonators, and validate detected device signals. In one particular embodiment described below, an AP is configured to detect a first type of device signal (e.g., BLE signal) and a second type of device signal (e.g., WiFi signal) from a computing device within an environment. The AP determines whether to relay location information regarding the computing device, based on an evaluation of the first type of device signal and the second type of device signal. In some cases, for example, the second type of device signal can be used to validate the first type of device signal. That is, the AP can provide a confidence factor in the detected first type of device signal, based on a comparison of one or more properties of the first type of device signal and the second type of device signal. In this manner, embodiments can validate device signals detected by APs in an environment and avoid relaying spoofed (or fake) device signals.

Note that while many of the embodiments described herein use the scenario of a missing computing device within an environment as a reference example of a scenario in which the techniques described herein can be utilized, embodiments herein can be used in other scenarios. In some embodiments, for example, the techniques presented herein can be used to aid contact tracing. In these embodiments, embodiments can determine the location of a user (via the user's computing device) that has been potentially exposed to an illness (e.g., via contact with another user or place).

FIG. **3** illustrates an example workflow **300** for validating device signals detected from a computing device, according to one embodiment. Here, the AP **206** includes a detection component **308** and a validation component **310**, each of which can include software components, hardware components, or combinations thereof. The AP **206** may be within the vicinity of the client device **304**. The client device **304** is representative of a variety of computing devices, including, but not limited to, a laptop, smartphone, a tablet, etc. In one embodiment, the client device **304** may be a lost or missing device (e.g., lost device **104**) within an environment (e.g., environment **102**). In another embodiment, the client device **304** may be associated with a user that is a target of a contact trace.

The AP **206** (via the detection component **308**) detects a BLE signal **302** and/or a WiFi signal **312** transmitted from the client device **304**. The detection component **308** can obtain a vendor identifier (e.g., organizational unique identifier (OUI)) associated with the client device **304** from the BLE signal **302**. Assuming the vendor identifier is an OUI, for example, the vendor identifier may include the first 24 bits of the media access control (MAC) address for the client device **304**. The detection component **308** can also obtain information (e.g., MAC address, signal strength/level, etc.) regarding the client device **304** from the WiFi signal **312**.

The AP **206** (via the validation component **310**) can determine whether the vendor identifier obtained from the BLE signal **302** is a valid vendor identifier. For example, the validation component **310** can determine whether the OUI is associated with a valid vendor/manufacturer. In addition to determining that the vendor identifier is valid, the AP **206** (via the validation component **310**) can use the information obtained by the detection component **308** to validate the BLE signal **302** from the client device **304**. For example, the validation component **310** can use the information to increase the confidence factor in the detection of the BLE signal **302**. For instance, the validation component **310** may determine a state/context (e.g., measured signal strength/level, range, etc.) from which it detected the client device **304**, based on the WiFi signal **312** (e.g., WiFi probe packet).

The AP **206** may use the obtained state/context information to increase the confidence in the validity of the BLE signal **302** detected from the client device **304**. The coexistence of both the WiFi signal **312** and the BLE signal **302** at similar range, for example, may provide additional confidence that the BLE signal **302** was not spoofed (e.g., the BLE signal **302** is not a fake signal **306** from a malicious actor **220**). For instance, if the validation component **310** determines that the comparison between the measured signal strength of the WiFi signal **312** and the measured signal strength of the BLE signal **302** satisfies a predetermined condition(s) (e.g., the measured signal strengths are similar, the difference between the measured signal strengths is within a threshold range, etc.), then the validation component **310** may determine that the BLE signal **302** is a valid signal as opposed to a fake signal **306**.

In some embodiments, the validation component **310** may include hardware (e.g., Sage chipset) and/or software that performs recording of a signature pattern of the client device **304**, based on the WiFi signal **312** and/or the BLE signal **302**. The signature pattern may include a signal level, signal interval (e.g., how often the signal is sent), stochasticity of the signal around a Gaussian/normal value, RF location determination, etc. In some cases, the validation component **310** may use an extended Kalman filter to normalize the signal and limit the effect of RF changes. In situations where the BT/BLE radio and/or WiFi radio of the AP **206** is connected to multiple antennas, the validation component **310** can obtain a RF location determination by performing a signal comparison across the multiple antennas.

In some embodiments, the validation component **310** can store the signature pattern of the client device **304** and use to the signature pattern to perform validation of the BLE signal **302**. For example, the validation component **310** can detect impersonations of the client device **304** based on signal(s) that have the wrong RF signature or changing RSSI levels. In another example, the validation component **310** can detect movements of the client device **304** based on deviations from the signal accepted ranges (associated with the signature pattern). In yet another example, the validation component **310** can compare the signal interval of the BLE signal **302** against a known signal interval (associated with the vendor identifier) to determine whether the BLE signal **302** is a valid signal. If the difference between the signal intervals satisfies a predetermined condition (e.g., difference is above a threshold), the validation component **310** may flag the detected signal as a fake signal **306**.

As shown in FIG. **3**, the AP **206** sends a message **314** with signal information to the computing device **202**. The signal information, for example, may include the BLE signal **302**, information regarding the BLE signal (e.g., vendor identifier, signal strength, signal interval, detected movement, detected impersonation, etc.). In one embodiment, the signal information is sent after validating the BLE signal **302**. In another embodiment, the signal information is sent to indicate that the BLE signal **302** is a fake signal **306** (e.g., the signal information may indicate a detected impersonation of the BLE signal **302**). In another embodiment, the signal information includes an indication of detected movement of the client device **304**.

The computing device **202** includes a location component **320**, which is configured to determine an approximate location (e.g., location information **322**) of the client device **304**, based in part on the signal information. In one embodiment, if the signal information is obtained from a single AP (e.g., a single AP is reporting), then the location information **322** includes the location of the single reporting AP and proximity to the single reporting AP. In another embodiment, if the signal information is obtained from multiple APs (e.g., multiple APs are reporting), then the location information **322** includes the location of the client device **304** (e.g., the location component **320** may use one or more triangulation techniques to determine the location of the client device **304**, based on the signal information from the multiple APs). The location information **322** may also include a timestamp indicating the time when the BLE signal **302** was detected. The computing device **202** may send the location information **322** and/or the signal information (not shown) to the vendor computing service **140**.

FIG. **4** is a flowchart of a method **400** for validating device signals (e.g., BLE signals **302**) detected from a computing device (e.g., client device **304**), according to one embodiment. The method **400** may be performed by one or more components of an AP (e.g., AP **206**).

The method **400** may enter at block **402**, where the AP detects and receives a first type of signal (e.g., BLE signal **302**) from a computing device (e.g., client device **304**) within an environment (e.g., environment **102**). At block **404**, the AP receives, if detected, a second type of signal (e.g., WiFi signal **312**) from the computing device within the environment. At block **406**, the AP evaluates the first type of signal and, if available, the second type of signal. For example, the AP may obtain a vendor identifier (e.g., OUI) from the first type of signal and validate the vendor identifier. The AP may evaluate the signal strengths of the first type of signal and the second type of signal. The AP may determine a signature pattern of the computing device, based on the first type of signal and/or the second type of signal.

At block **408**, the AP determines whether the evaluation satisfies one or more conditions. In one embodiment, for example, the AP determines whether the first type of signal is valid, based on a comparison of one or more signal parameters (e.g., measured signal strength) of the first type of signal and the second type of signal. For instance, if difference between the measured signal strengths of the first type of signal and the second type of signal is within a threshold difference, then AP can determine (or verify) that the first type of signal is valid. Otherwise, the AP can determine that the first type of signal is invalid. In another embodiment, the AP determines whether the first type of signal is valid, based on a signature pattern associated with the computing device. For example, if one or more parameters of the first type of signal is consistent with the signature pattern, then the AP can determine (or verify) that the first type of signal is valid.

If the AP determines that the evaluation satisfies the conditions, then the AP sends information regarding the first type of signal (e.g., message **314**) to another computing device (e.g., computing device **202**) (block **410**). On the other hand, if the AP determines that the evaluation does not satisfy the condition(s), then the AP refrains from sending at least some information regarding the first type of signal (block **412**). The method **400** may then exit.

In some embodiments, the AP **206** may perform object detection based on the BLE signal(s) **302** detected from the client device **304**. FIG. **5** illustrates one example workflow **500** for performing object detection, according to one embodiment. As shown, the AP **206** is coupled to a computing system **502**, which includes a video tool **504**. Note, the AP **206** may be coupled to the computing system **502** via a wired or wireless link. In one embodiment, the computing system **502** is an internet protocol video system (IPVS). The video tool **504** can capture images and/or record a video feed of the client device **304**.

For example, upon detecting a BLE signal **302**, the AP **206** can use the video tool **504** to capture a feed of the client device **304**. The AP **206** can determine a shape of the client device **304**, based on the vendor identifier from the BLE signal **302**, and detect the client device **304** from the video feed by associating the device shape to the location of the BLE signal **302**. In one embodiment, the AP **206** may store images of the client device **304**, as movement of the client device **304** is detected. The AP may send the captured images (e.g. image information **506**) to the computing device **202**. The computing device **202** may send the image information **506** to the vendor computing service **140**.

FIGS. **6**A-**6**C illustrate a workflow **600** for managing a message relaying system, according to one embodiment. As shown in FIG. **6**A, one or more APs **206 1**-K (in vicinity of the client device **304**) detect a BLE signal **302** broadcasted by the client device **304**. The APs **206 1**-K then send messages **314 1**-K including signal information to the computing device **202**. In one embodiment, the computing device **202** (via the location component **320**) makes a primary reporter determination **604**, based on the messages **314 1**-K. In one embodiment, the location component **320** makes the primary reporter determination **604** after determining that one or more conditions are satisfied (e.g., the device position is stable over a predetermined time interval).

In one embodiment, the location component **320** determines which of the APs **206 1**-K has received the strongest BLE signal **302** from the client device **304**, and designates that AP as the primary reporter. As shown in FIG. **6**B, for example, the location component **320** designates the AP **206-1** as the primary reporter, and sends a message **606** with the primary reporter indication to the AP **206-1**. The location component **320** may designate the remaining reporter APs **206 2**-K as secondary reporters. For example, in FIG. **6**B, the location component **320** sends a hold message **608** to each of the remaining reporter APs **206 2**-K. In one embodiment, the hold message triggers the APs **206 2**-K to stop reporting the messages **314 2**-K. As shown in FIG. **6**C, for example, the primary reporter AP **206-1** continues reporting to the computing device **202** and the secondary reporter APs **206 2**-K refrain from reporting to the computing device **202**.

In some embodiments, the hold message **608** may cause the secondary reporter AP **206** to refrain from reporting while a certain set of conditions are satisfied. For example, the hold message **608** may cause a secondary reporter AP to stop reporting the OUI (and signal information) as long as the client device **304** is detected by the secondary reporter AP and/or is detected within configurable boundaries (e.g., no impersonation detection, no movement, RSSI is within a configurable stochasticity range, etc.). The secondary reporter APs **206 2**-K may resume reporting if one of the conditions changes.

Similarly, when the primary reporter AP **206-1** detects a change (e.g., movement, impersonation, signal stops, signal interval change, etc.), the primary reporter AP **206-1** may report the change to the location component **320**. The location component **320**, in response, may query each of the secondary reporter APs **206 2**-K for their respective status, and determine whether to change the primary reporter designation, based on the statuses.

As shown in FIG. **6**C, the location component **320** sends location information **322** to the vendor computing service **140**. As noted, the location information **322** can be used by a device owner to identify the client device **304**. For example, a user can obtain the computed location of the client device **304**, along with a timestamp of the last detection. In this manner, embodiments can significantly improve location mechanisms that rely solely on the presence of transient computing devices (e.g., passing mobile devices) to determine the location of lost devices.

FIG. **7** is a flowchart of a method **700** for managing a message relaying system, according to one embodiment. The method **700** may be performed by one or more components of a computing device (e.g., computing device **202**).

The method **700** may enter at block **702**, wherein the computing device receives multiple messages (e.g., messages **314**) from multiple APs. Each message, for example, may include an encrypted BLE signal and/or related signal information (e.g., signal strength, RF signature pattern, etc.) obtained by an AP from a client device (e.g., client device **304**).

At block **704**, the computing device selects, based on an evaluation of the messages, one of the APs as the primary reporter. For example, the computing device may select the AP that has detected the BLE signal with the highest signal strength as the primary reporter. At block **706**, the computing device generates and transmits a message (e.g., message **606**) with an indication of the primary reporter designation to the primary reporter AP. At block **708**, the computing device generates and transmits, to each remaining reporting AP, a hold message (e.g., hold message **608**) instructing the AP to refrain from reporting (e.g., while certain conditions are satisfied).

At block **710**, the computing device determines whether a change in one or more conditions is detected. For example, the computing device can receive an indication from the primary reporter AP and/or one or more of the secondary reporter APs indicating that there has been a change in one or more conditions. The condition change can include at least one of detected movement, detected impersonation, signal stops, signal interval change, and change in signal level, change in RF signature, etc. If the computing device determines there has been a change in condition(s), then the computing device requests the status from each of the multiple APs (block **712**). The computing device can then perform another primary reporter designation (e.g., by performing blocks **704-710**). If the computing device determines there has not been a change in condition(s), the method **700** exits.

FIG. **8** is a flowchart of another method **800** for managing a message relaying system, according to one embodiment. The method **800** may be performed by one or more components of a computing device (e.g., computing device **202**).

The method **800** may enter at block **802**, where the computing device receives information regarding a client device (e.g., client device **304**) from an AP (e.g., AP **206**). For example, the computing device may receive a message **314** that includes signal information (e.g., encrypted BLE signal, detected movement indication, impersonation detected, etc.) associated with the client device.

At block **804**, the computing device determines an estimated location of the client device, based on the information. In the case of a single reporting AP, the computing device can determine the estimated location in terms of the proximity to the single reporting AP. In the case of multiple reporting APs, the computing device can use triangulation techniques to determine the estimated location of the client device.

At block **806**, the computing device generates and transmits a message that includes location information (e.g., location information **322**) to a computing system (e.g., vendor computing service **140**). The location information may include an indication of the estimated location of the client device, a timestamp indicating when the client device was detected, a location of the AP (that reported to the computing device), etc. In some cases, if the client device is detected as moving, then the computing device may include the detected locations of the client device as a time series (e.g., in a location history). In some embodiments, the location information includes GPS information. In some embodiments, in addition to or in alternative to GPS information, the location information includes detailed information regarding an indoor environment (e.g., building, particular floor, particular room, etc.) where the AP is located. For example, the computing device can obtain the detailed information regarding the indoor environment from a real-time locating system (RTLS) associated with the environment.

At block **808**, the computing device determines whether an indication of one or more reporting conditions has been received (e.g., from the AP(s)). The reporting condition(s) can include, for example, an indication of detected movement, an indication of impersonation or spoofing attempt, an indication that the client device stopped sending a signal, an indication of a change in signal parameters (e.g., message pattern has changed), and the like. If the computing device has received an indication of a reporting condition, then the computing device can generate a message to indicate the reporting condition(s) (block **810**).

For example, if the computing device receives an indication from the reporting AP that the client device has stopped sending a device signal, then the computing device can report to the computing system (e.g., vendor computing service **140**) that the computing device has not moved, but has stopped sending a device signal. This may indicate to the computing system that the client device has an empty battery.

In another example, the computing device may parse the device signal received from the AP to determine whether the device signal is being impersonated, whether the client device has been recovered, etc. For instance, although the device signal may not be decodable by the computing device (e.g., the device signal is encrypted), the computing device can expect that the same message will be sent by the client device at a given location. The computing device can therefore use this information to verify that the message pattern is not changing over time and being impersonated. Additionally, if the computing device determines that the client device has stopped sending the signal, but then detects that the same source MAC address starts sending other device signals (e.g., other BT/BLE signals), the computing device can report this to the computing system (e.g., vendor computing service **140**). This situation may indicate that the client device has become active and is no longer in "rescue me" mode.

In another example, each time that an event is reported (e.g., changing RSSI, movement, impersonation, etc.), the computing device (at block **810**) can send the message to an administrator. The administrator (e.g., building management, security personnel, IT administrator, etc.) may have an established trust relationship with the environment and the owner of the client device. The administrator can then access the lost device location to retrieve the client device. Once retrieved, the administrator can send a message indicating the retrieval of the client device (e.g., Lost-and-Found have taken ownership") to the computing device. Once the retrieval message is received, the computing device may continue to report the device location to the vendor computing service **140**, but may refrain from reporting events related to movement of the client device.

In another example, when device movement is detected and/or when the RF footprint changes (due to, e.g., impersonation, incoherent signal range, etc.), the computing device can generate and send a "watch" instruction to the reporting AP(s). These AP(s) can then report the device signals detected from other MAC addresses within the signal range of the client device (e.g., signaling other BT/BLE devices at the same location). In one embodiment, the computing device performs a hyperbolas correlation to confirm the location of the other detected BT/BLE devices. The computing device may perform a similar process for WiFi signals at the same location of the client device. In one embodiment, the computing device uses a Bayesian inference to sort the various signals reported at the client device location and determine the set of devices that are associated with the client device location as the client device moves (e.g., those devices with maximum likelihood of being associated with the client device).

If, at block **808**, the computing device has not received an indication of a reporting condition, the computing device determines whether a stop tracking request has been received (block **812**). If a stop tracking request has been received, then the computing device refrains from sending location reports to the vendor computing service **140** (block **814**). The method **800** then exits. If a stop tracking request has not been received, then the method **800** proceeds to block **802**.

In some embodiments, the computing device **202** can keep track of lost and/or missing devices within an environment and send the location information regarding client devices to legal intercept organizations. This information can then be used for analytics (e.g., if there is a pattern of stolen devices appearing in a certain location) to determine whether additional security is needed at the location of the lost devices.

In some embodiments, the computing device **202** acts as an aggregation point for multiple vendor computing services. FIG. **9** illustrates an example system **900** for interacting with multiple vendor computing services, according to one embodiment. Here, the computing device **202** has a connection to multiple vendor computing services **140** A-N. The computing device **102** acts as an aggregation point to send data out to each of the vendor computing services **140**

A-N. In this manner, the computing device **202** is able to replay BLE detection to one or more multiple different vendor device locating clouds.

FIG. **10** illustrates an example computing device **1000**, according to one embodiment. The computing device **1000** can be configured to perform one or more techniques described herein for validating device signals detected from a client device **304**. The computing device **1000** includes a processor **1010**, a memory **1020**, and one or more communication interfaces **1030***a-n* (generally, communication interface **1030**). In one embodiment, a first set of communication interfaces **1030** are used for communicating WiFi signals, and a second set of communication interfaces **1030** are used for communicating BT/BLE signals. In various embodiments, the computing device **800** is an AP.

The processor **1010** may be any processing element capable of performing the functions described herein. The processor **1010** represents a single processor, multiple processors, a processor with multiple cores, and combinations thereof. The communication interfaces **1030** facilitate communications between the computing device **1000** and other devices. The communications interfaces **1030** are representative of wireless communications antennas and various wired communication ports. The memory **1020** may be either volatile or non-volatile memory and may include RAM, flash, cache, disk drives, and other computer readable memory storage devices. Although shown as a single entity, the memory **1020** may be divided into different memory storage elements such as RAM and one or more hard disk drives.

As shown, the memory **1020** includes various instructions that are executable by the processor **1010** to provide an operating system **1022** to manage various functions of the computing device **1000**. As shown, the memory **1020** includes the operation system **1022**, detection component **308**, validation component **310**, and one or more application(s) **1050**.

FIG. **11** illustrates an example computing device **1100**, according to one embodiment. The computing device **1100** can be configured to perform one or more techniques described herein for managing a message relaying system. The computing device **1100** includes a processor **1110**, a memory **1120**, and one or more communication interfaces **1130***a-n* (generally, communication interface **1130**). In various embodiments, the computing device **1100** is representative of a server computing device. In some embodiments, the computing device **1100** is located in a cloud computing environment.

The processor **1110** may be any processing element capable of performing the functions described herein. The processor **1110** represents a single processor, multiple processors, a processor with multiple cores, and combinations thereof. The communication interfaces **1130** facilitate communications between the computing device **1100** and other devices. The communications interfaces **1130** are representative of wireless communications antennas and various wired communication ports. The memory **1120** may be either volatile or non-volatile memory and may include RAM, flash, cache, disk drives, and other computer readable memory storage devices. Although shown as a single entity, the memory **1120** may be divided into different memory storage elements such as RAM and one or more hard disk drives.

As shown, the memory **1120** includes various instructions that are executable by the processor **1110** to provide an operating system **1122** to manage various functions of the computing device **1100**. As shown, the memory **1120** includes the operation system **1122**, location component **320**, and one or more application(s) **1150**.

In the current disclosure, reference is made to various embodiments. However, the scope of the present disclosure is not limited to specific described embodiments. Instead, any combination of the described features and elements, whether related to different embodiments or not, is contemplated to implement and practice contemplated embodiments. Additionally, when elements of the embodiments are described in the form of "at least one of A and B," it will be understood that embodiments including element A exclusively, including element B exclusively, and including element A and B are each contemplated. Furthermore, although some embodiments disclosed herein may achieve advantages over other possible solutions or over the prior art, whether or not a particular advantage is achieved by a given embodiment is not limiting of the scope of the present disclosure. Thus, the aspects, features, embodiments and advantages disclosed herein are merely illustrative and are not considered elements or limitations of the appended claims except where explicitly recited in a claim(s). Likewise, reference to "the invention" shall not be construed as a generalization of any inventive subject matter disclosed herein and shall not be considered to be an element or limitation of the appended claims except where explicitly recited in a claim(s).

As will be appreciated by one skilled in the art, the embodiments disclosed herein may be embodied as a system, method or computer program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, embodiments may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

Computer program code for carrying out operations for embodiments of the present disclosure may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Aspects of the present disclosure are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatuses (systems), and computer program products according to embodiments presented in this disclosure. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the block(s) of the flowchart illustrations and/or block diagrams.

These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other device to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the block(s) of the flowchart illustrations and/or block diagrams.

The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process such that the instructions which execute on the computer, other programmable data processing apparatus, or other device provide processes for implementing the functions/acts specified in the block(s) of the flowchart illustrations and/or block diagrams.

The flowchart illustrations and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments. In this regard, each block in the flowchart illustrations or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the block diagrams and/or flowchart illustrations, and combinations of blocks in the block diagrams and/or flowchart illustrations, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

In view of the foregoing, the scope of the present disclosure is determined by the claims that follow.

We claim:

1. A computer-implemented method performed by a first computing system, the computer-implemented method comprising:

receiving a plurality of first messages from a plurality of access points (APs), each first message of the plurality of first messages being from a respective AP of the plurality of APs and comprising information regarding a device signal received by the respective AP from a computing device;

selecting, based on an evaluation of each of the plurality of first messages, a first AP of the plurality of APs as a primary reporting AP;

transmitting, to the first AP, a second message comprising an indication that the first AP is the primary reporting AP; and

after transmitting the second message, forwarding the first message received from the first AP to a second computing system.

2. The computer-implemented method of claim **1**, further comprising transmitting a third message to each second AP of the plurality of APs, the third message comprising an instruction for the second AP to refrain from reporting information regarding the device signal received by the second AP to the first computing system.

3. The computer-implemented method of claim **1**, further comprising receiving an indication of a reporting condition from at least one of the first AP and one or more second APs of the plurality of APs, wherein the reporting condition comprises at least one of a movement of the computing device, impersonation of the computing device, and a change in one or more signal parameters of the device signal.

4. The computer-implemented method of claim **3**, further comprising:

in response to receiving the indication of the reporting condition, transmitting a status request to each of the plurality of APs; and

determining, based on the status requests, whether to select another one of the plurality of APs as the primary reporting AP.

5. The computer-implemented method of claim **1**, further comprising:

receiving a stop tracking request from the second computing system; and

after receiving the stop tracking request, refraining from forwarding subsequent messages received from the first AP to the second computing system.

6. The computer-implemented method of claim **1**, wherein the information comprises the device signal and a timestamp indicating when the device signal was detected by the respective AP.

7. The computer-implemented method of claim **1**, further comprising:

receiving an indication from the first AP that the computing device has stopped sending the device signal; and

in response to receiving the indication, transmitting to the second computing system a third message indicating that the computing device has stopped sending the device signal and that the computing device has not moved.

8. The computer-implemented method of claim **1**, further comprising:

receiving a first indication from the first AP that the computing device has stopped sending the device signal;

after receiving the first indication, receiving a second indication, from at least a second AP of the plurality of APs, that another device signal has been received by the second AP from the computing device; and

in response to the second indication, transmitting to the second computing system a third message indicating that the computing device has resumed sending device signals.

9. A first computing system comprising:

one or more memories collectively storing instructions; and

one or more processors coupled to the one or more memories, the one or more processors being collectively configured to execute the instructions to cause the first computing system to perform an operation comprising:

receiving a plurality of first messages from a plurality of access points (APs), each first message of the plurality of first messages being from a respective AP of the plurality of APs and comprising information regarding a device signal received by the respective AP from a computing device;

selecting, based on an evaluation of each of the plurality of first messages, a first AP of the plurality of APs as a primary reporting AP;

transmitting, to the first AP, a second message comprising an indication that the first AP is the primary reporting AP; and

after transmitting the second message, forwarding the first message received from the first AP to a second computing system.

10. The first computing system of claim **9**, the operation further comprising transmitting a third message to each second AP of the plurality of APs, the third message comprising an instruction for the second AP to refrain from reporting information regarding the device signal received by the second AP to the first computing system.

11. The first computing system of claim **9**, the operation further comprising receiving an indication of a reporting condition from at least one of the first AP and one or more second APs of the plurality of APs, wherein the reporting condition comprises at least one of a movement of the computing device, impersonation of the computing device, and a change in one or more signal parameters of the device signal.

12. The first computing system of claim **11**, the operation further comprising:

in response to receiving the indication of the reporting condition, transmitting a status request to each of the plurality of APs; and

determining, based on the status requests, whether to select another one of the plurality of APs as the primary reporting AP.

13. The first computing system of claim **9**, the operation further comprising:

receiving a stop tracking request from the second computing system; and

after receiving the stop tracking request, refraining from forwarding subsequent messages received from the first AP to the second computing system.

14. The first computing system of claim **9**, wherein the information comprises the device signal and a timestamp indicating when the device signal was detected by the respective AP.

15. The first computing system of claim **9**, the operation further comprising:

receiving an indication from the first AP that the computing device has stopped sending the device signal; and

in response to receiving the indication, transmitting to the second computing system a third message indicating that the computing device has stopped sending the device signal and that the computing device has not moved.

16. The first computing system of claim **9**, the operation further comprising:

receiving a first indication from the first AP that the computing device has stopped sending the device signal;

after receiving the first indication, receiving a second indication, from at least a second AP of the plurality of APs, that another device signal has been received by the second AP from the computing device; and

in response to the second indication, transmitting to the second computing system a third message indicating that the computing device has resumed sending device signals.

17. A non-transitory computer-readable storage medium comprising instructions that, when collectively executed by one or more processors associated with a first computing system, cause the first computing system to perform an operation comprising:

receiving a plurality of first messages from a plurality of access points (APs), each first message of the plurality of first messages being from a respective AP of the plurality of APs and comprising information regarding a device signal received by the respective AP from a computing device;

selecting, based on an evaluation of each of the plurality of first messages, a first AP of the plurality of APs as a primary reporting AP;

transmitting, to the first AP, a second message comprising an indication that the first AP is the primary reporting AP; and

after transmitting the second message, forwarding the first message received from the first AP to a second computing system.

18. The non-transitory computer-readable storage medium of claim **17**, the operation further comprising transmitting a third message to each second AP of the plurality of APs, the third message comprising an instruction for the second AP to refrain from reporting information regarding the device signal received by the second AP to the first computing system.

19. The non-transitory computer-readable storage medium of claim **17**, the operation further comprising receiving an indication of a reporting condition from at least one of the first AP and one or more second APs of the plurality of APs, wherein the reporting condition comprises at least one of a movement of the computing device, impersonation of the computing device, and a change in one or more signal parameters of the device signal.

20. The non-transitory computer-readable storage medium of claim **19**, the operation further comprising:

in response to receiving the indication of the reporting condition, transmitting a status request to each of the plurality of APs; and

determining, based on the status requests, whether to select another one of the plurality of APs as the primary reporting AP.

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